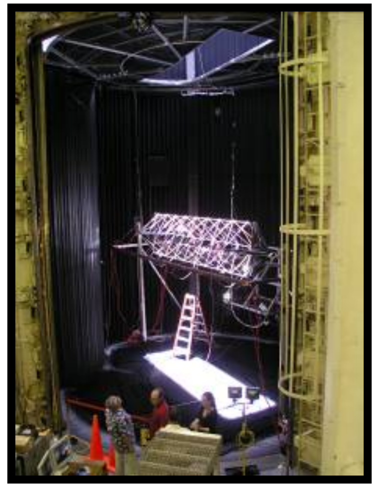
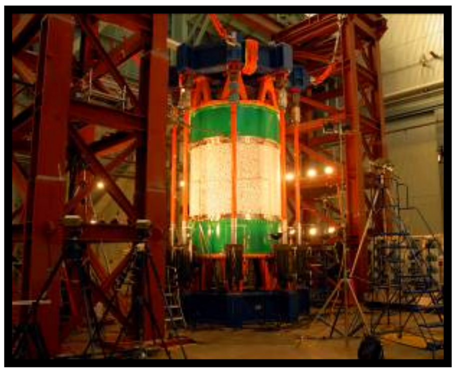
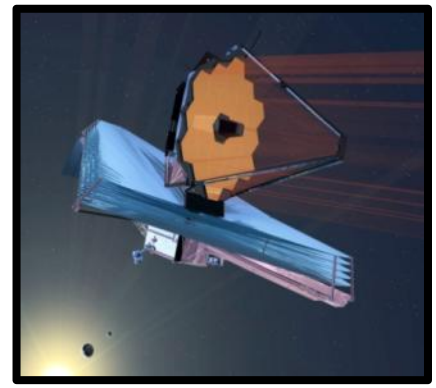





NASA Engineering and Safety Center Overview

October 2014




Bottom Line – Up Front

Engineering Excellence

- ✓ Independent technical assessment is a critical component of the safety and mission success of NASA's program
- ✓ NESC has established itself as the "value added" independent test and analysis organization for the Agency with over 500 Assessments in 9 + years
- ✓ NESC was a key contributor to the Space Shuttle Program return to flight and the safe and successful fly-out of the program
- ✓ NESC workload remains high and is distributed across all of NASA missions
- ✓ The Centers provide outstanding support to the NESC
- ✓ With two human space flight programs in development, one in operation, and multiple earth and planetary science programs in every lifecycle phase, ***a robust independent technical capability*** is necessary for NASA to continue to accomplish its mission

NESC Background and Mission

Engineering Excellence

Apollo Saturn 5 Launch Vehicle

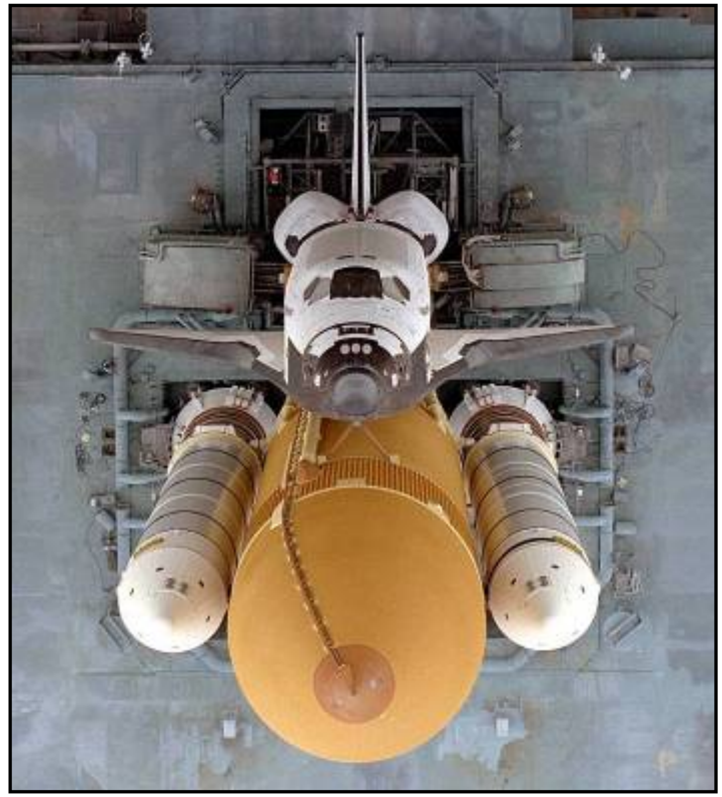
- ✓ NESC was established in July 2003 in response to the Columbia accident
- ✓ Built on NASA's traditional safety philosophy:
  - *Strong in-line checks and balances*
  - *Healthy tension between organizational elements*
  - *Value-added independent assessment*
- ✓ NESC provides independent assessment of technical issues for NASA programs and projects

NESC is cultivating a Safety culture focused on ***engineering and technical excellence***, while fostering an ***open environment*** and attacking challenges with ***unequalled tenacity***

NESC Model

Engineering Excellence

- ✓ Institutionalized "Tiger Team" approach to solving problems
- ✓ Agency-recognized NASA Technical Fellows lead Technical Discipline Teams (TDT)
  - *"Ready" experts from across NASA, industry, academia and other agencies*
  - *Diverse, expert technical teams provide robust technical solutions*
- ✓ Assemble independent, diverse, expert technical teams that provide robust technical solutions to the Agency's highest-risk and most complex issues
  - *NESC involvement ranges from supporting reviews, augmenting project teams, and solving problems through independent test and analysis, to exploring alternate design concepts*
- ✓ Strong Systems Engineering function for proactive trending and identification of problem areas before failures occur

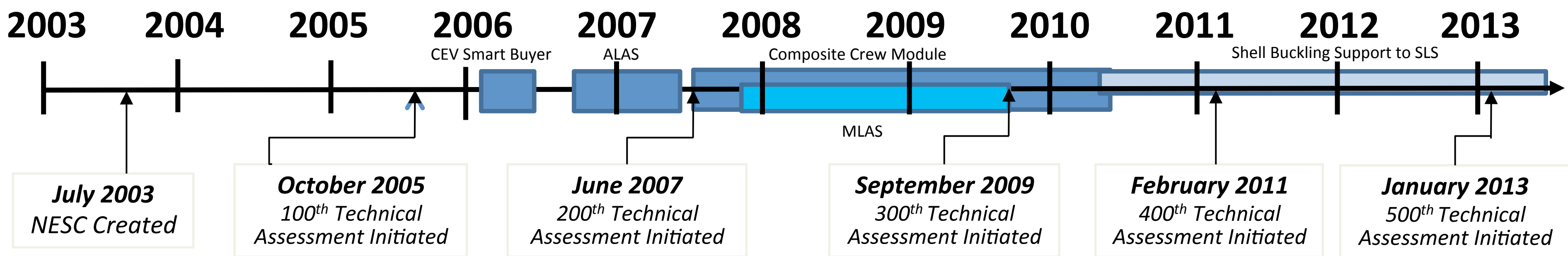


Space Shuttle on Mobile Launch Platform

Focus on technical rigor and engineering excellence

NESC Timeline

Engineering Excellence



NESC Leadership Team

The NESC provides a strong technical team to coordinate and conduct robust, independent engineering and safety assessments across the Agency.

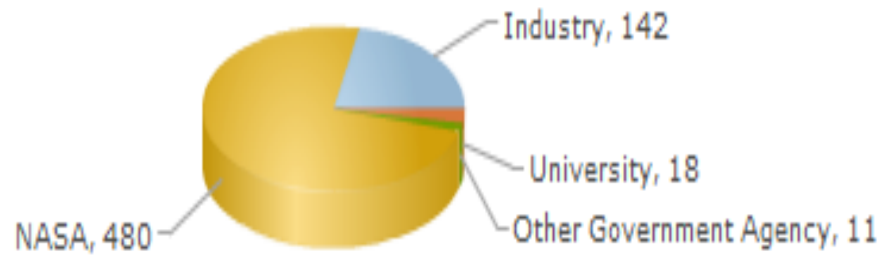
NESC Organization

Distributed NESC Team

Engineering Excellence

- ✓ NESC has ~60 full-time employees selected from across the Agency and externally
- ✓ NESC Chief Engineers at each Center provide technical insight and liaison roles
- ✓ 15 NASA Technical Fellows are recognized experts in their respective engineering fields
- ✓ 18 Technical Discipline Teams (TDT) comprised of 16 engineering and 2 operations disciplines create a network of over 650 engineers available for matrix support

TDT Participation by Affiliation



Over 650 national engineering experts support the NESC nationwide

- ✓ More than 200 TDT members are intentionally drawn from industry, academia and other government agencies to prevent insularity
- ✓ Participation on NESC teams provides value to home organizations
  - *Valuable problem-solving experience*
  - *Broad Agency-wide perspective*

NASA Technical Fellows

Engineering Excellence


Michael Aguilar
Software
GSFC


Thomas Brown
Propulsion
MSFC


Neil Dennehy
GN&C
GSFC


Michael Dube
Mechanical
Systems
GSFC


Oscar González
Avionics
GSFC


Chris Iannello
Power
KSC


Curtis Larsen
Loads & Dynamics
JSC


Daniel Murri
Flight Mechanics
LaRC


Cynthia Null
Human Factors
ARC


Robert Piascik
Materials
LaRC


William Prosser
NDE
LaRC


Ivatury Raju
Structures
LaRC


Steven Rickman
Passive Thermal
JSC


Henry Rotter
Fluids, ECLS &
Active Thermal
JSC


David Schuster
Aerosciences
LaRC

NASA Technical Fellows

Engineering Excellence

- ✓ Outstanding senior-level engineers and scientists with distinguished and sustained records of technical achievement
- ✓ Agency's leading experts in their respective technical disciplines
- ✓ Maintain NESC Technical Discipline Teams with ready-experts
- ✓ Provide leadership and act as role models for NASA discipline engineering communities beyond the Technical Discipline Teams
- ✓ Provide technical consistency across NASA through inputs to Agency-level specifications and standards and the tailoring of those standards for programs and projects
- ✓ Promote discipline stewardship through workshops, conferences and assorted discipline-advancing activities
- ✓ Ensure lessons learned are identified, widely shared across engineering organizations, and incorporated into Agency processes
- ✓ Conduct discipline specific gap analyses to identify areas that require strategic investment to develop fundamental engineering sciences

NASA Chief Engineers

Engineering Excellence

- ✓ Liaison between resident Center and NESC
- ✓ Proactive involvement with programs and projects at resident Center
- ✓ Provide technical expertise and technical resources external to the program/project to assist with resolving issues
- ✓ Provide program/project insight to rest of NESC through participation at major boards and panels
- ✓ Review assessment requests, clarify issue, perform risk assessment, recommend NESC course of action, develop associated cost ROM, and present to NESC Review Board
- ✓ Manage NESC resources at resident center
- ✓ Assist Principal Engineers and NASA Technical Fellows staff NESC technical activities with resident Center resources
- ✓ Contribute to Technical Discipline Teams and NESC technical activities – both assessments and support activities – based on their areas of expertise

NESC Chief Engineers

- AFRC – Lance Richards
- ARC – Nans Kunz
- GSC – Dawn Emerson
- GSFC – Joe Pellicciotti
- JPL – Lloyd Keith
- JSC – Scott West
- KSC – Steve Minute
- LaRC – Jill Prince
- MSFC – Steve Gentz
- SSC – Mike Smiles

The NESC Assessment Team

Engineering Excellence

Assessment Team

NESC Core Team

- **NESC Principal Engineers**
  Assessment Team Leads
- **NESC Chief Engineers**
  NESC Points of Contact at each Center
- **NASA Technical Fellows**
  Senior Technical Experts
- **Management and Technical Support Office**
  Contracts, Budgets, Partnerships
- **Systems Engineering Office**
  Systems Engineering and Technical Integration

18 Technical Discipline Teams

Aerosciences
Avionics
Electrical Power
Flight Mechanics
Guidance, Navigation & Control
Human Factors
Human Spaceflight Operations
Life Support/Active Thermal
Loads and Dynamics
Materials
Mechanical Systems
Non-Destructive Evaluation
Passive Thermal
Propulsion
Robotic Spaceflight
Software
Structures
Systems Engineering

NESC Matrix Team

- **NASA Engineers at the division and directorate levels of each Center**
- **Industry Experts**
- **Members of the Academic Community**

Performing NESC Assessments

Overview Flowchart

Engineering Excellence

Assessment Team

NESC Review Board

Request Submitted (from anyone) → Request Processed, Evaluated and Accepted → Assessment Team Formed; Plan Developed and Approved → Proceed with Assessment (Testing, Modeling, Analysis, Data Collection) → Peer Review and Document Findings, Observations and Recommendations → Deliver Final Report to Stakeholders

NESC Review Board

NESC requests evaluated on risk for the Agency and NESC task priorities (currently primarily focused on priorities 1 and 2):

1. *Technical support of projects in the flight phase*
2. *Technical support of projects in the design phase*
3. *Known problems not being addressed by any project*
4. *Work to avoid potential future problems*
5. *Work to improve a system*

NESC RISK ASSESSMENT

Purpose: The NESC risk assessment is used to communicate one factor in the initial evaluation of requests for NESC independent assessments and technical support. The NESC risk matrix supports the evaluation and prioritization of Program/project technical risks from an overall Agency perspective.

RISK DEFINITIONS

Risk: Measure of the potential inability to achieve overall program objectives within defined constraints and has two components: (1) the probability/likelihood of failing to achieve a particular outcome, and (2) the consequences/ impacts of failing to achieve that outcome.

Likelihood: Chance of a risk occurring within a stated timeframe.

Consequences: Impacts (typically categorized as negative) to program/project (i.e., hardware and/or science loss, injury, illness, and environmental damage)

Note: A risk scenario can be written as a statement; "given a defined condition, there is a possibility (likelihood) that a consequence(s) will occur." The estimates of likelihood and consequences may have associated uncertainties.

RISK MANAGEMENT: An organized, systematic decision-making process that efficiently identifies risks, assesses or analyzes risks, communicates risks, and effectively reduces or eliminates risks to achieving program goals.

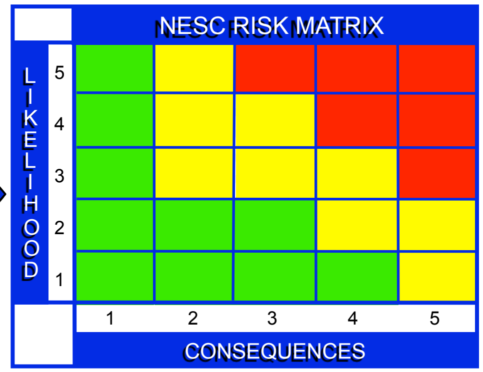
RISK SCORING METHODOLOGY: The NESC focuses on technical risks. Risk scoring is accomplished by numerical value which is reflective of the ordered pair Likelihood (L), Consequence (C). The highest score is represented in the NESC Risk Matrix as a single score value.

How likely is this condition, situation, or risk scenario?

LIKELIHOOD

Level	*Probability*	*Qualitative Guidance (Crewed and Non-Crewed Missions)*	*Quantitative Guidance: Crewed Missions*	*Quantitative Guidance: Non-Crewed Missions*
5	Highly Likely	Likely to occur multiple times. Existing controls have little or no effect.	Estimated probability greater than 0.10 (>10%)	Estimated probability greater than 0.50 (>50%)
4	Likely	Expected to occur. Existing controls have serious uncertainties or limitations.	Between 0.01 and 0.10 (1% - 10%)	Between 0.25 and 0.50 (25% - 50%)
3	Moderate	Significant potential to occur. Existing controls have some uncertainties or limitations.	Between 0.001 and 0.01 (0.1% - 1%)	Between 0.05 and 0.25 (5% - 25%)
2	Unlikely	Unlikely but possible to occur. Existing controls have minor uncertainties or limitations.	Between 0.000001 and 0.001 (0.0001% - 0.1%)	Between 0.01 and 0.05 (1% - 5%)
1	Highly Unlikely	Not likely to occur. Strong controls are in place.	Less than 0.000001 (< 0.0001%)	Less than 1% (< 1%)

NESC RISK MATRIX



LEGEND

- High – Probable NESC independent assessment (IA) or technical support.
- Medium – NESC, other NASA IA org. and/or Program/project action may be required.
- Low – No NESC action required. May be referred to another NASA IA organization.

RISK CONSEQUENCE SCORING

Safety, Health, and Environment consequences include adverse impacts to life, health, working environments, and/or natural environments.

Mission Success consequences include hardware losses and/or adverse impacts to science returns as defined by Major Mission Objectives (MMOs).

Safety, Health, Environment, and Mission Success consequences can exist concurrently and are not mutually exclusive.

If the risk scenario occurs, what are the consequences?

CONSEQUENCES

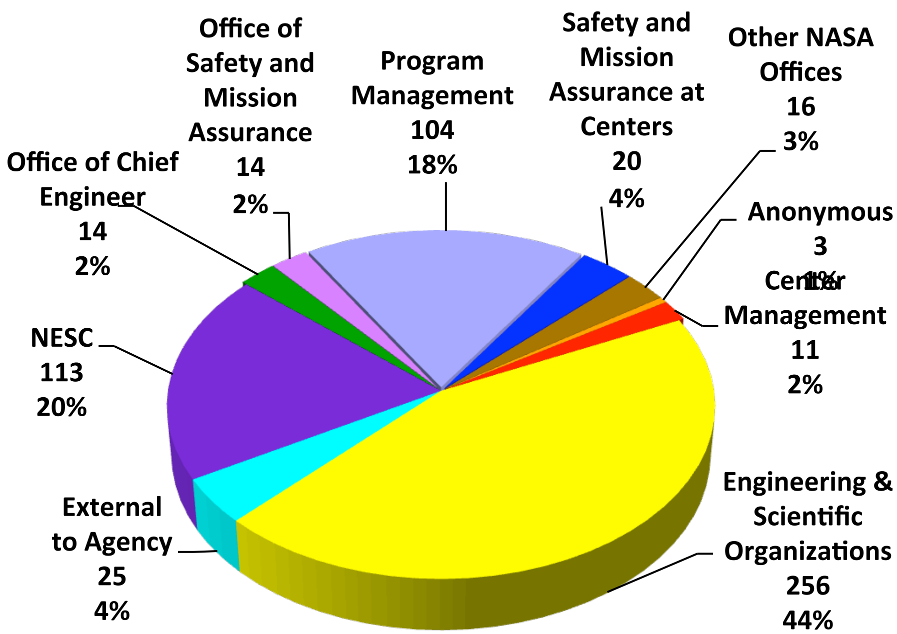
Level	1	2	3	4	5
Safety, Health, & Environment	Minimal/no safety or health plan violations; Minimal/ no environmental impacts	Could result in injury or illness not resulting in lost work days; Minimal environmental damage	Could result in injury or illness resulting in one or more lost work days; Mitigatable env. damage	Could result in permanent partial disability; Reversible environmental damage	Could result in death or permanent total disability ; Irreversible severe environmental damage
Mission Success (Crewed & Non-Crewed Missions)	Hardware loss < $100K and/or Failure to meet any one Major Mission Objective (MMO)	Hardware loss $100k -$1M and/or Failure to meet > 10% of MMOs	Hardware loss $1M - $10M and/or Failure to meet > 25% of MMOs	Hardware loss $10M - $50M and/or Failure to meet > 50% MMOs	Hardware loss > $50 M and/or Failure to meet all MMOs

Updated: February 2012

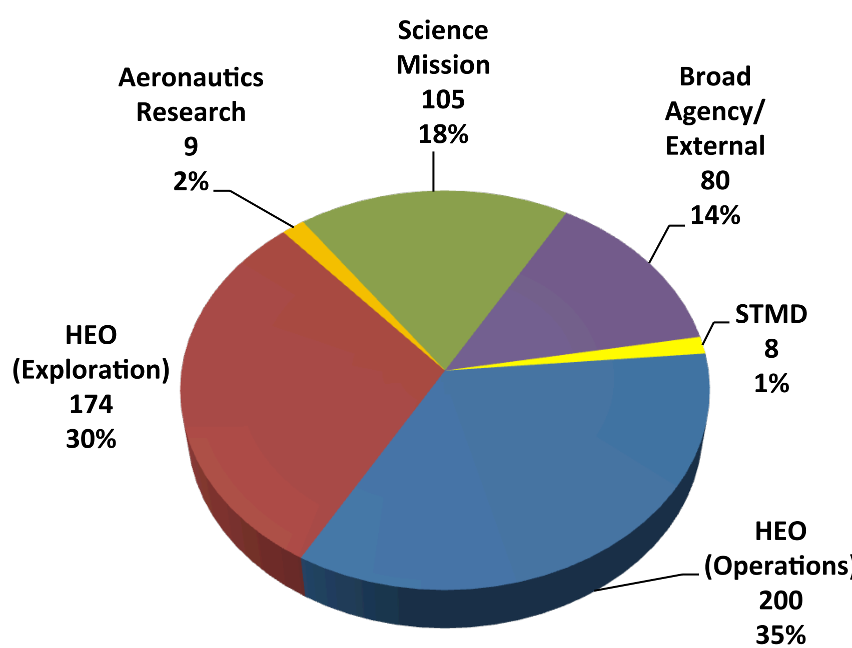
Accepted Requests

Engineering Excellence

Sources



Mission Directorates



Total Requests = 576

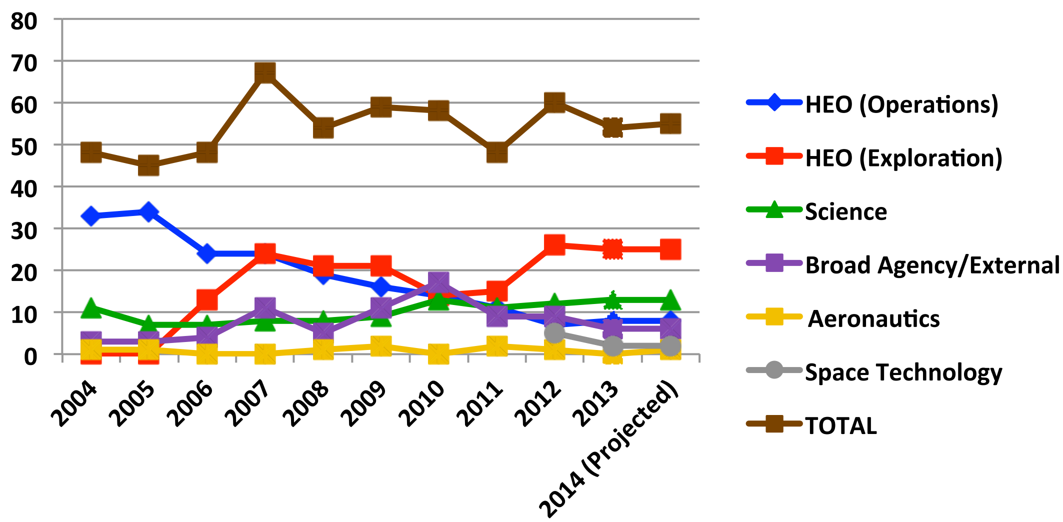
Data as of May 28, 2014

NESC Activities Trends

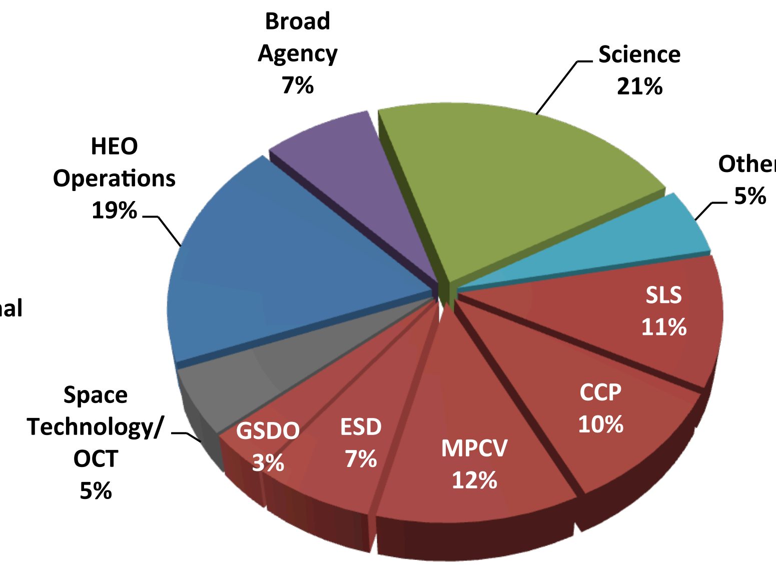
Accepted Requests per Year

Engineering Excellence

FY 2004 - 2014



FY 2012-2014



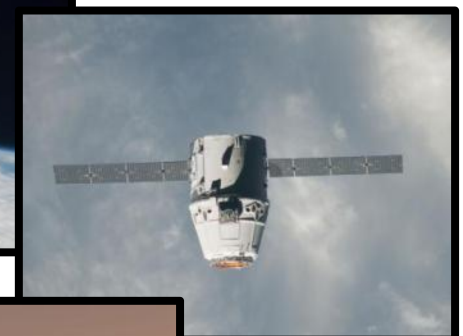
Data as of May 28, 2014

- ✓ Annual traffic volume of assessments has been consistent at ~50/yr
- ✓ The make up of the assessment traffic has shifted from primarily Space Operations to a good mixture of all of NASA's Mission Directorates
- ✓ Expect continued growth in new human spaceflight programs

NESC Technical Highlights

Engineering Excellence

- ✓ The NESC focuses on the Agency's most critical programs
  - *The NESC's emphasis has moved from the Space Shuttle Program to the new human spaceflight and science mission programs*



- ✓ The NESC is filling the increasing need of ensuring safety through independent, engineering excellence
  - *Two new human spaceflight programs are currently in development – the best time to provide strong technical input*
  - *International Space Station in operation*
  - *Robust earth and planetary science programs*

- ✓ The NESC is a place to turn for help addressing difficult decisions
  - *Provide decision makers impartial, data-driven inputs to address dissenting opinions or multiple alternatives*

Typical NESC Activities

Projects in Operations or Flight Phase

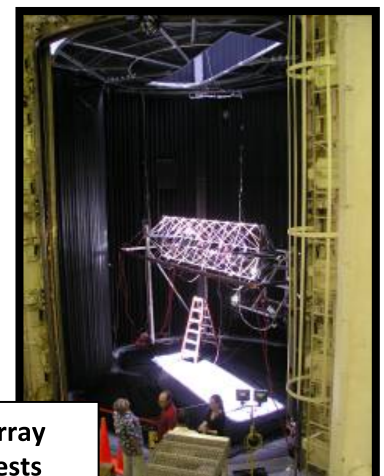
Engineering Excellence

✓ Provide real-time problem solving for programs and projects in operations or flight phase

- *Space Shuttle External Tank Stringer Cracking Issue*
- *Space Shuttle Orbiter Wing Leading Edge Reinforced Carbon-Carbon Spalling Issue*
- *ISS Control Moment Gyroscope (CMG) Performance Investigation*
- *ISS Solar Array Mast Shadowing Assessment*
- *EVA Glove Damage Root Cause Determination*
- *Hubble Space Telescope Attitude Observer Anomaly*

Stringer Testing
Greg Shanks *LaRC*

CMG Flywheel Modal Testing

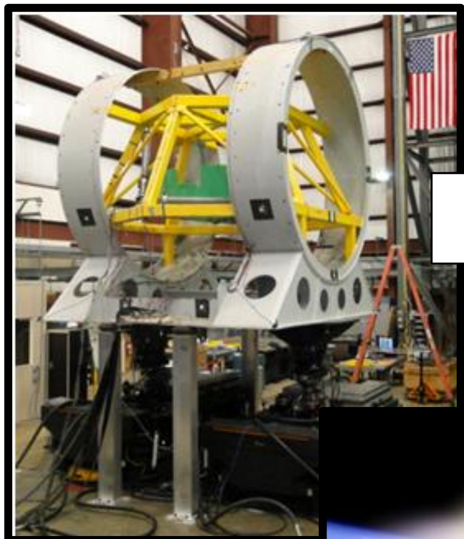


ISS Solar Array Thermal Tests

Typical NESC Activities

Projects in Development

Engineering Excellence



Thrust Oscillation System Under Test

Illustration of Orion Crew Module During Re-Entry

Lester Langford *SSC*

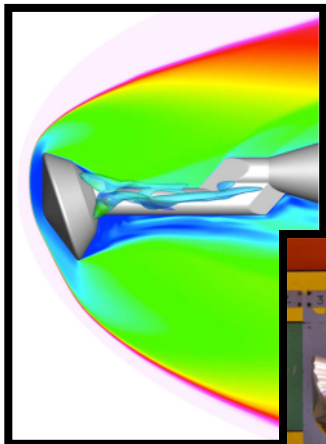
✓ Conduct independent testing and analysis for the next generation of launch vehicles and spacecraft

- *Structural Dynamics Analysis Review of Stennis Space Center A-3 Test Stand*
- *Empirical Launch Vehicle Explosion Model Evaluation*
- *Crew Module Water Landing Modeling*
- *Certification of Chute Systems for High Altitude Deployments*
- *Exploration Systems Independent Modeling and Simulation*
- *Orion Thermal Protection System Margin Study*
- *Development of Orion Crew Seat Energy Attenuation Mechanical Concepts*

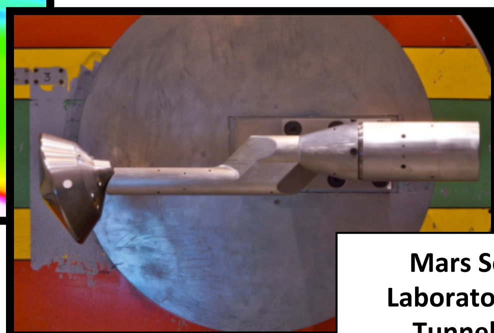
Typical NESC Activities

Robotic Spacecraft and Aeronautics Projects

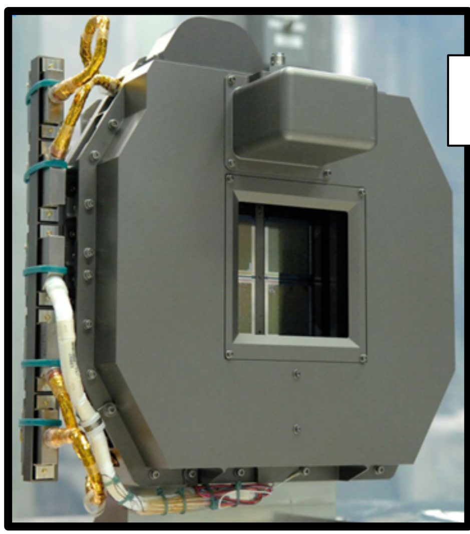
Engineering Excellence



Mars Science Laboratory Computational Fluid Dynamics



Mars Science Laboratory Wind Tunnel Tests



NIRSpec Instrumentation

Hypersonic Air Breathing Launch Vehicle Study

✓ Support the development of critical robotic spacecraft and aeronautics missions

- *Mars Science Laboratory Aero/ Reaction Control System Interaction Model Validation*
- *Mars Science Laboratory Ground Test and Checkout Review*
- *James Webb Space Telescope Thermal Shield Venting Analysis*
- *James Webb Space Telescope NIRSpec Micro Shutter Subsystem*
- *Hypersonic Air Breathing Launch Vehicle Study*

Typical NESC Activities

Improving System Safety and Performance

Engineering Excellence

- ✓ Improve system performance and increase system safety
  - *Shell Buckling Knockdown Factor*
- ✓ Investigate alternate design concepts to inform program baseline designs
  - *Max Launch Abort System*
  - *Composite Crew Module*
  - *Crew Seat Energy Attenuation Mechanism*

Shell Buckling Knockdown Factor Test

Mark Hilburger *LaRC*
Michael Roberts *MSFC*

Max Launch Abort System Team
Sarah Quach *KSC*
Gary Dittemore *JSC*

Typical NESC Activities

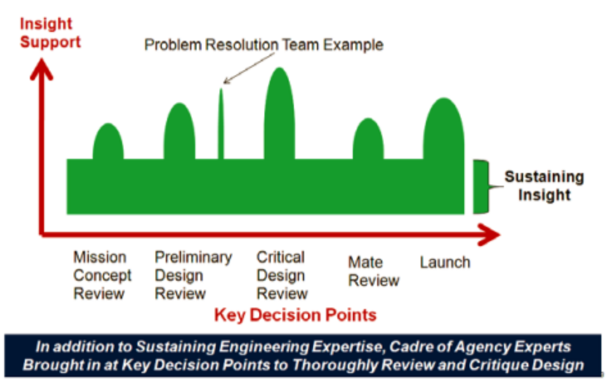
Commercial Crew Projects

Engineering Excellence

Composite Crew Module

Crew Module Water Landing Modeling Assessment

Commercial Crew Program Temporal Insight Support Approach



- ✓ Share best practices and lessons learned with new commercial partners
  - *Launch Abort Systems*
  - *Landing Systems & Water Landing*
  - *Constructing Aerodynamic Databases using Computational Fluid Dynamics (CFD) and Wind Tunnel Testing*
  - *Aerodynamic Testing and Database Development*
  - *Composite Spacecraft Design*
  - *Rendezvous and Proximity Operations*

- ✓ NESC technical expertise is specifically called out in the Commercial Crew Program Insight Plan
  - *Provide surge capability and temporal support as required*
  - *Based on engagement to date, the demand for NESC engagement will grow significantly*

Typical NESC Activities

Resolving Cross-Cutting Challenges

Engineering Excellence

Composite Overwrap Pressure Vessel Team
Thomas Hanson *WSTF*
Marene Carillo *WSTF*

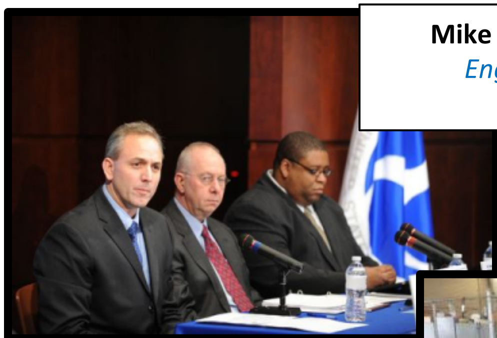
High Precision Ball Bearings

- ✓ Resolve critical Agency cross-cutting technical challenges
  - *COPV Life Prediction Model Development*
  - *Shock-Proof and Corrosion Immune Bearings*
  - *Reaction Wheel Assembly Lubricant Contamination*
- ✓ Develop engineering guidelines and recommended best practices
  - *NASA Fault Management Practitioners Handbook*
  - *Determining Readiness for Crewed Flight on New Spacecraft Systems*
  - *NASA Models and Simulations Guidebook*
  - *Technology Roadmap Teams*

Typical NESC Activities

Supporting Other Government Agencies

Engineering Excellence



Mike Kirsch, *NESC Principal Engineer, with NHTSA representatives*

NHTSA Investigation Team Members:
Dr. Phillip Tang *KSC*
Omar Torres *LaRC*

Air Force F-22

Chilean Miner Rescue

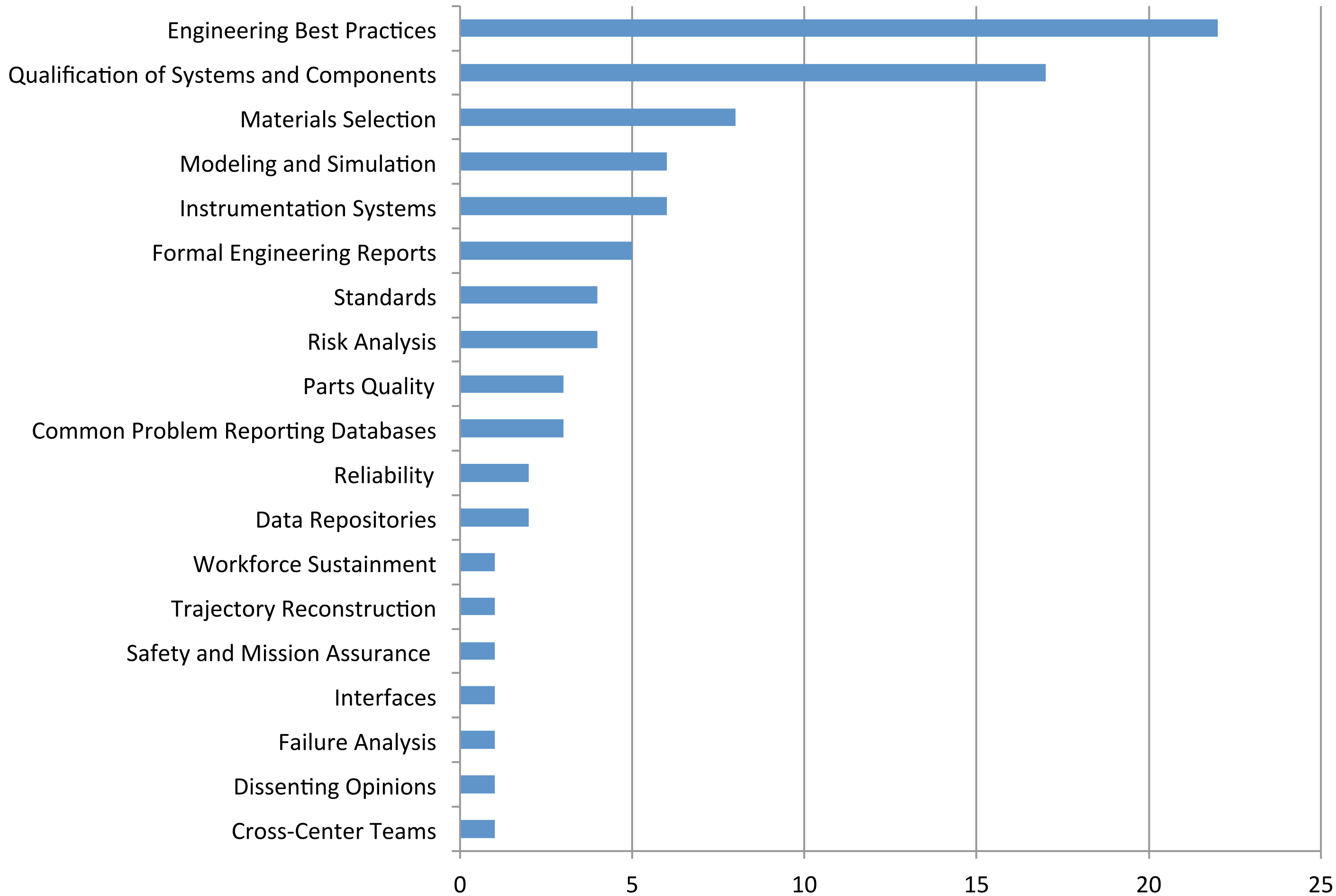
✓ Provide technical support to investigations outside the Agency

- *National Highway Traffic Safety Administration (NHTSA) Unintended Acceleration Investigation*
- *Rescue of trapped Chilean miners*
- *British Royal Navy Self-Contained Oxygen Generator Failure Investigation*
- *Impact of Unsteady Loads on the Tail Appendages of the Navy Advanced SEAL Delivery System (ASDS) Vehicle*
- *Los Alamos National Laboratory (LANL)/ Nuclear Explosive Safety Team Threaded Fastener Guidance*
- *Air Force F-22 Life Support System Independent Analysis*

NESC Common Lessons Learned

Data Base from NESC Assessments

Engineering Excellence



NESC Common Lessons Learned

Top 4 Lessons Learned Area Breakdown

Engineering Excellence

- Engineering Best Practices
  - Spacecraft Large Pressure Vessels
  - Systems engineering/ Project management
  - Uncertainty Characterization of Wind Tunnel Force Measurement Systems
  - Pneumatic components of Wind Tunnel Force Balance Systems
  - Avoid Consensus Opinion over Data
  - Rendezvous and Docking Navigation Systems
  - Loctite as a Secondary Fastener
  - Diverse Teams
  - Composite Spacecraft Pressure Vessel Construction
  - Finite Element Modeling
  - Design of Solid Rocket Motors
  - Control of Mass Properties
  - System Life Cycle Design
  - Design Reviews
  - Nondestructive Evaluation
  - Preventing Crew Induced Damage
  - Avionics Cooling
- Qualification of Systems and Components
  - Test as You Fly
  - Requalification for New Missions
  - Components Exceeding Certification Life
  - Testing
  - Inspection and Analysis
  - Ground Service Equipment
- Materials Selection
  - Misapplication of materials
  - Document Material Properties
  - Benefits of composite materials
  - Effects of Materials Substitution
  - Best Practices for use of Titanium
- Modeling and Simulation
  - Understanding Code Limitations
  - Use with Limited Validation
  - Inter-model Correlation
  - Understand Boundary Conditions
  - Model Verification
  - Plan for Model Development

Summary and Challenges

Engineering Excellence

- ✓ After almost 10 years and 500+ technical assessments the NESC has become the "value added" independent technical organization for the Agency the CAIB envisioned
- ✓ NESC workload remains high despite Shuttle retirement and completion of ISS assembly. Thank you to the Centers for their continued support!
- ✓ The NESC model provides an excellent example of the benefits of agency wide collaboration to solve the complex engineering problems.
  - *Creative, robust technical solutions*
  - *Stronger checks and balances*
  - *Well informed decision making*
- ✓ History has taught us that a ***strong focus on safety and mission assurance*** is easier right after a critical event – but ***maintaining the same level of vigilance*** in the years that follow is required to prevent future accidents